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COMPATIBILITY AND LATERALITY EFFECTS IN DIRECTIONAL INFORMATION DISPLAYS

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ABSTRACT

Stimulus-response (S-R) compatibility effects were examined in a series of experiments investigating mental representations of the directions "right" and "left". In a simple word-picture verification task, both laterality and S-R compatibility showed strong effects using right-handed subjects. Displays with the term "right" took less time to verify than those with the term "left", and compatible manual responses were faster than the incompatible. When the task was made more complex, no compatibility effect was found. In two picture verification tasks, laterality effects did not appear but the compatibility effects remained strong. Finally, a similar task was modified to eliminate the S-R compatibility effect, and the right-left directionality effect once again emerged. These results are discussed in terms of the cognitive processes involved in interpreting the spatial terms and in mapping the spatial codes for response.

It has often been demonstrated that compatibility between the stimulus and the response exerts a strong effect in human information processing tasks. In general, the paradigm for such investigations consists of choice reaction time measures where the subject must make responses which, more or less, either naturally correspond or do not correspond to a given set of stimuli (Fitts and Seeger, 1953). In the compatible situation, where the subject is instructed to make a motor response in correspondence with the stimulus, facilitation is said to occur and reaction times are faster; in the incompatible situation where the response is counter to the stimulus, interference occurs and reaction times are longer (Wallace, 1971).

This effect has been shown in several sense modalities. Fitts and Seeger (1953), among others, have demonstrated stimulus-response (S-R) compatibility with visual stimuli, Broadbent and Gregory (1965) with tactual stimulation, and Simon, Hinrichs, and Craft (1970) with auditory stimuli. In each of these studies, one or more parameters in addition to the S-R compatibility were varied, such as stimulus probability or number of response alternatives. In all of these experiments S-R compatibility proved to be the most potent factor affecting performance. Clearly the power of S-R compatibility makes it interesting to members of our profession, since it is a variable that produces differences which are significant practically as well as statistically.

At the Naval Submarine Medical Research Laboratory we have studied S-R compatibility as an important topic in human factors research in itself, and as a gauge of the potency of other variables. Initially prompted by findings from some of our studies of problem solving in anti-submarine warfare, our research has been concerned with the human factors implications of spatial organization in perceptual and cognitive processing.

In a series of experiments investigating mental representations of the directions "right" and "left," S-R compatibility effects were again observed. In contrast to other studies of compatibility, however, where there is a straight-forward spatial correspondence between the stimulus and the response, compatibility in the present investigations involved implied or referenced spatial directions. In some of the tasks a lateralized bias in information processing occurred, while in others, the bias appeared attenuated by the powerful influence of S-R compatibility. In one task, however, the lateral processing bias persisted but the compatibility effect was insignificant. The present paper will review these studies and discuss their differential findings.

EXPERIMENT 1

Method

To determine if the two spatial terms RIGHT and LEFT were processed differently, as had been found earlier for the terms ABOVE and BELOW by Seymour (1969) and Chase and Clark (1971), subjects were asked to make true-false judgments about word-picture displays (Olson and Laxar, 1973). The four displays used in this experiment are shown in Figure 1 and were patterned after those used by Seymour, and Chase and Clark. It was hypothesized that the term RIGHT would represent a normative direction and yield faster verification times than the term LEFT, as had been found by the earlier investigators with the term ABOVE giving faster decision times than BELOW.

The displays were presented in a tachistoscope, and responses were made on true and false keys to either side of the subject's centerline. A hands crossed position was never

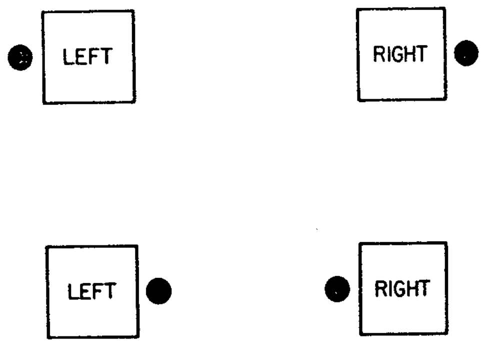

Figure 1. The four displays used in Experiments 1 and 2.

used, and the labeling of the response keys, true or false, was counterbalanced across subjects.

As the subject initiated each trial, one of the four displays flashed on. The subject had to decide whether the word accurately described the position of the dot and make the appropriate true or false response as quickly as possible, which then turned the display off. Subjects were given a warm-up and 96 experimental trials, in a single session. Twelve right-handed men with normal or corrected vision served as subjects.

Results

Mean latencies for correct responses only were entered into a repeated-measures analysis of variance, which indicated that displays with the word RIGHT were verified significantly faster than those with LEFT, as listed in Table 1. Other effects proved significant, as well, but discussion will be confined to the matters of present interest.

In this experiment which induced strong directional biases, S-R compatibility effects were also evident. These can be summarized in the following way. For each subject one of the *true* displays referred to the same side as the *true* response key, and this represented a compatible (C) relationship. The other display represented an incompatible (IC) relationship. The arrangement was similar for the *false* displays. For each subject the average difference between the correct reaction times for C and IC (IC - C) was computed for *true* and *false* responses separately. A series of *t* tests was calculated testing these means against zero and against each other. These means and results of the *t* tests are also shown in Table 1. Subjects were significantly faster on *true* C responses than on *true* IC responses, and no difference was found for *false* responses.

To help determine if faster times obtained

TABLE 1

Mean Latencies, and Laterality and Compatibility Effects for Experiments 1-5

	Experiment	Grand Mean	RIGHT-LEFT Effect		S-R Compatibility Effect: True Response		False Response		True vs. False
				F(*df*)	IC-C	*t*(*df*)	IC-C	*t*(*df*)	*t*(*df*)
		msec	msec		msec		msec		
1	Word-picture Verification	737	94	13.10** (1,11)	116	2.23* (11)	17	<1 (11)	1.39 (11)
2	Reversed Perspective	887	73	8.28* (1,14)	12	<1 (14)	31	<1 (14)	<1 (14)
3	Arrows	619	7	<4 (1,11)	104	4.68** (11)	8	<1 (11)	4.65** (11)
4	Line of sight Absolute/Relative	1225	28	2.95 (1,12)	171	6.85** (13)	49	2.64* (13)	4.72** (13)
5	Line of sight Absolute only	608	47	17.93** (1,22)	-------		-------		-------

*p<0.05
**p<0.01

for RIGHT displays were due to biases in mentally representing the spatial terms, or merely a result of coincident visual scanning in reading the word and locating the dot, two additional experiments were conducted. First, Experiment 2 was run with subjects instructed to interpret the displays from the perspective of someone facing them rather than from their own perspective, reversing the mapping of the physical layout of the displays onto the true-false responses. Second, Experiment 3 was run with arrows substituted for the words, eliminating the mental representation of the words RIGHT and LEFT from the task. The predictions were that the first manipulation would not change the asymmetry effects found in Experiment 1, while the second one would essentially eliminate them. The effect of S-R compatibility should persist in both instances, however.

EXPERIMENT 2

Method

This experiment was identical to Experiment 1, except that subjects were instructed to interpret the dot positions and the words RIGHT and LEFT as referring to the right and left of a person facing them. The mapping of true and false responses into the displays was therefore reversed. Subjects were 15 right-handed men.

Results

Mean latencies and an analysis of variance were computed in the same manner as for Experiment 1. The overall response times were substantially longer than in Experiment 1, due to the more complex task. Although the displays were interpreted differently than in the previous experiment, those with RIGHT were still verified faster than displays with LEFT. No compatibility differences of any kind, however, emerged in this experiment. These results are listed in Table 1.

EXPERIMENT 3

Method

This study was identical to Experiment 1 except that in place of RIGHT and LEFT in the center of the boxes, were arrows pointing in the direction indicated by the term it replaced. Subjects were instructed to respond true when the arrow pointed to the side of the box on which the dot appeared and false when it did not. No mention of right or left was made in the instructions. Twelve men served as subjects.

Results

Mean reaction times and the analysis of variance were computed as before. As predicted, shown in Table 1, no laterality differences were found, but the compatibility differences were significant.

The results of these studies are taken as evidence that the mental representation of RIGHT is faster than that of LEFT. The data provide evidence that the effect arises during the central information processing that occurs in reaching a decision, rather than in transfer effects from scanning or reading habits (see Olson and Laxar, 1973).

S-R compatibility showed strong effects in two of the studies, as well. In Experiment 2, however, a more complex task in which subjects had to transform the information in the displays before making a response, compatibility effects were apparently masked or eliminated.

EXPERIMENT 4

Two additional studies were conducted to determine if the previously found directional biases exerted influence in more applied tasks, namely the interpretation of shipboard navigational displays depicting own ship and target ship motion.

Method

In this experiment (Laxar and Olson, 1978), subjects were asked to make true-false decisions about agreement in the lateral directions implied by a pair of vector diagrams. These "line of sight" (LOS) diagrams, three examples of which are shown in Figure 2, are frequently used to solve tactical and navigational problems at sea. The subject's task was to mentally perform a vector subtraction between the target and own ship's motion portrayed by the two vectors in the absolute diagram (upper portion of Figure 2), obtaining an implicit direction of relative motion vector. He was then to decide if the vector

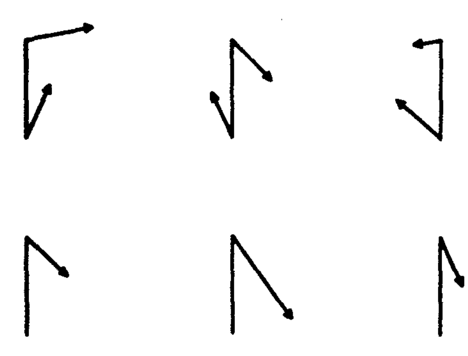

Figure 2. Three examples of Line of Sight displays used in Experiments 4 and 5, showing all true cases, with direction of relative motion to the right.

in the relative diagram (lower portion of Figure 2) correctly depicted this relative motion, left or right, and press the appropriate true or false key.

Twelve representative tactical situations were used. The angle and the length of the relative motion vector were correct for each situation, but to obtain the false displays, the vector was shown reflected to the opposite side. Each of these displays were then also reversed right for left, making a total of 48 different displays with equal numbers of each of the following: motion from the absolute diagram to the right, motion to the left, true, and false. Subjects were 14 U.S. Navy Submarine School Officers of varying experience, all of whom, however, were familiar with the use of these LOS diagrams. All subjects wrote with their right hand, and had normal or corrected vision.

The procedure was similar to that used before, except the displays were presented on a computer-driven Tektronix 4010 display terminal, and the keys used for responding were those at the ends of the bottom row of the keyboard. Each subject was run in two sessions of 192 trials each. The labeling of the response keys was counter-balanced across subjects, and for each subject's second session was reversed.

Results

An analysis of variance was computed for mean latencies of correct responses. In this study no right-left differences were significant.

The effects of S-R compatibility were then assessed as before: the compatible relationship existed when the resultant direction implied by the absolute diagram was the same as the position of the true response key. Otherwise, an incompatible relationship existed. As indicated in Table 1, S-R compatibility effects were more potent than in any of the other experiments. Not only was the effect significant for true responses, but also for false responses, and for the difference between true and false as well.

The question then arises of what happened to the lateral biases which were so robust in the previous, more simple tasks. Did the exclusive use of arrows in Experiment 4 eliminate the mental representations of RIGHT and LEFT, as it had in Experiment 3? Or did the extremely powerful compatibility effects found here overshadow the laterality effects? One more experiment was conducted.

EXPERIMENT 5

Method

In this experiment (Laxar and Beare, in preparation), an attempt was made to eliminate any S-R incompatibility in interpreting the LOS diagrams. Another group of Submarine School Officers, 24 right-handers, served as subjects. The displays used this time were only the absolute LOS diagrams, i.e. as examples, just the upper portions of the displays shown in Figure 2. These were slightly enlarged and centered on the face of the display terminal screen, for presentation as in Experiment 4. The subjects were instructed to decide whether the direction of relative motion shown in the diagram was to the right or to the left, and to press the response key on that same corresponding side with the corresponding forefinger. Therefore, the true and false part of the decision process was eliminated making the task less complex, and all responses were compatible. Subjects were run in 4 blocks of 24 trials each, plus practice, in a single session.

Results

Once again, mean latencies were subjected to an analysis of variance. In this experiment, however, a highly significant right-left effect was observed. In this simpler task, the overall response time was about half that of Experiment 4, while the right-left difference was substantially larger, as shown in Table 1.

DISCUSSION

Compatibility between a stimulus and a response has long been shown to have a profound effect over a broad range of decision making tasks. In the set of studies presented here S-R compatibility was seen to affect and be affected by the nature of the information processing task at hand. In the case of simple word-picture verification of Experiment 1, where a strong right-left effect was seen, the compatibility effect existed for true displays but not for the false. In Experiment 3, where arrows were substituted for the directional terms, the right-left effect was eliminated, but the compatibility effects were similar to Experiment 1, strong for true responses, but nonexistent for false. With a reversed perspective, Experiment 2, RIGHT was faster than LEFT, but no compatibility differences were seen. In this instance, where the task was more complex, the extra step of mentally transforming the spatial relationships apparently removed the corresponding mapping of spatial codes that Wallace (1971) has argued plays a role in S-R compatibility. Compatibility effects were obtained only when the stimulus elements appeared on, or unambiguously referenced, a particular side.

In an even more complex task, Experiment 4, where subjects had to mentally resolve a pair of vectors, S-R compatibility effects were most robust. Thus it is not merely task complexity but the particular stages of the decision making process which alter compatibility effects. In Experiment 4 the processes of subtracting the vectors and comparing the mentally represented resultant with the relative vector diagram occurred prior to, and left intact, the straight-forward mapping of the spatial codes. The compatibility effects were so strong, in fact, that only in this case were they significant for the false responses, as well as the true. In addition, it is believed that the magnitude of the S-R compatibility effects completely overshadowed the right-left processing bias which was expected in this experiment. Evidence for this is given in Experiment 5, in which any response was highly compatible and the right-left effect proved significant. This task was less complex than that of Experiment 4 in other ways, as well, however. The subject did not have to make the comparison of the mental and displayed relative vectors, and did not have to map a true-false response to right-left keys, which could have contributed to the results obtained.

Although the above sequence of studies was designed to explore biases in mentally processing directional terms, it serves to illustrate the importance of S-R compatibility considerations. The relationship between the nature and complexity of the processing required in a given task and S-R compatibility effects deserves further exploration. Finally, the pervasiveness of S-R compatibility effects illustrated here should be kept in mind in evaluating the relationship among system parameters, the displays, and related controls.

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